DIRECTIONAL PATTERN ANALYSIS OF A LINEAR PHASED ANTENNA ARRAYS

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Summary: An antenna array is a system compound from simply radiators (dipoles, microstrip antennas), that together form desired radiation pattern. Phased array antennas consist of multiple stationary antenna elements, that are fed coherently and use variable phase or time-delay control at each element to scan a beam to given angles in space. Variable amplitude control is sometimes also provided for antenna pattern shaping.

1. INTRODUCTION

An antenna array is a system compound from simply radiators (dipoles, microstrip antennas), which together form desired radiation pattern. The main emphasis is on the width, contour and direction of orientation during form a radiation pattern of antenna system.

By the assistance this way of created patterns it is possible to rout a radiation energy of antenna system into desiderative direction, reduce interference and increase efficiency entire transmission.

In practice are known several techniques that can form radiation pattern of antenna system. The article deals with description of technique based on feeding particular elements antenna system by different phase signals. [1]

2. LINEAR ANTENNA ARRAY

An antenna array is a configuration of individual radiating elements that are arranged in space and can be used to produce a directional radiation pattern.

Single-element antennas have radiation patterns that are broad and hence have a low directivity that is not suitable for long distance communications.

A high directivity can be still achieved with single element antennas by increasing the electrical dimensions (in terms of wavelength) and hence the physical size of the antenna.

Antenna arrays come in various geometrical configurations, the most common being; linear arrays (1D).

Arrays usually employ identical antenna elements. The radiating pattern of the array depends on the configuration, the distance between the elements, the amplitude and phase excitation of the elements, and also on the radiation pattern of individual elements.

A uniform linear array consists of equispaced elements, that are fed with current of equal magnitude (i.e. with uniform weighting) and can have progressive phase-shift along the array. [2], [3]

There is displayed schematic diagram of linear antenna array in the Fig. 1. [4]

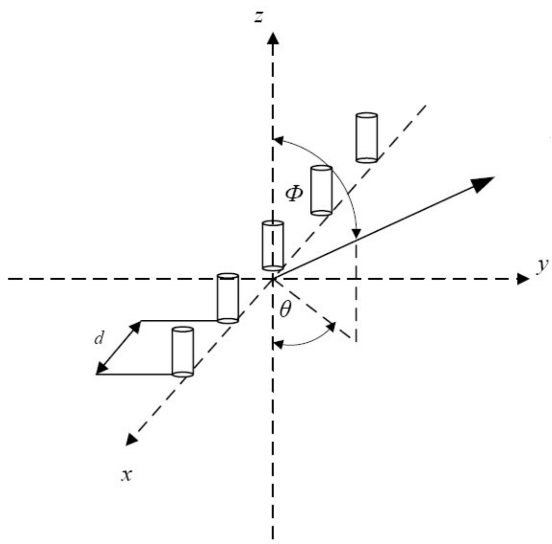


Fig. 1. Schematic diagram of linear antenna array

The uniform linear array shown in the Figure 1 consists of N elements equally spaced at distance d.

The Array factor for a linear array of N parallel elements is given by the relation (1).

$$AF = \frac{1}{N}\frac{\sin\left(\frac{N}{2}kd.\cos\theta+\varphi\right)}{\sin\left(\frac{1}{2}kd.\cos\theta+\varphi\right)}, 0 \le \theta \le \pi, \quad (1)$$

where:

- N is the number of elements
- d is the interelement space
- θ is the angle from the array axis
- φ is the phase shift

Symbol k represents wavelet number. The wavelet number is given by the relation (2).

$$k = \frac{2\pi}{\lambda}, \quad (2)$$

Where λ is the wavelength.

3. LINEAR PHASED ANTENNA ARRAY STEERING

Phased array antennas consist of multiple stationary antenna elements that are fed coherently and use variable phase or time - delay control at each element to scan a beam to given angles in space.

Variable amplitude control is sometimes also provided for pattern shaping. Arrays are sometimes used in place of fixed aperture antennas (reflectors, lenses), because the multiplicity of elements allows more precise control of the radiation pattern, thus resulting in lower sidelobes or careful pattern shaping.

However, the primary reason for using arrays is to produce a directive beam that can be repositioned (scanned) electronically. Although arrays with fixed (stationary) beams and multiple stationary beams will be discussed in this text, the primary emphasis will be on those arrays that are scanned electronically. [4]

There is displayed schematic diagram of linear phased antenna array beam - steering in the Figure 2.

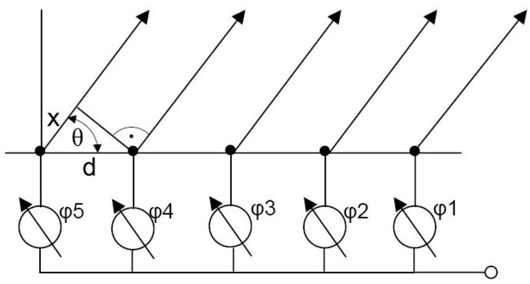


Fig. 2. Schematic diagram of phased linear antenna array beam - steering

The phase shift φ between two successive elements is constant and is called phase-increment.

We can derive these formulas from Figure 2:

$$x = d.cos\theta, \tag{3}$$

$$\frac{2\pi}{\varphi} = \frac{\lambda}{x}, \tag{4}$$

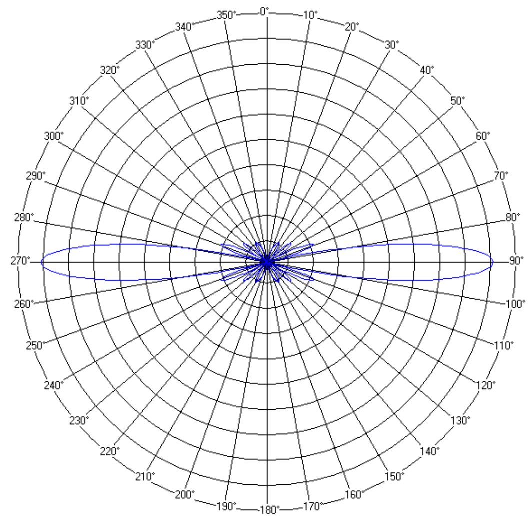
$$\varphi = \frac{2\pi}{\lambda} d.cos\theta, \tag{5}$$

Formula 3 describes the phase shift dependence on angle of main lobe orientation. [5]

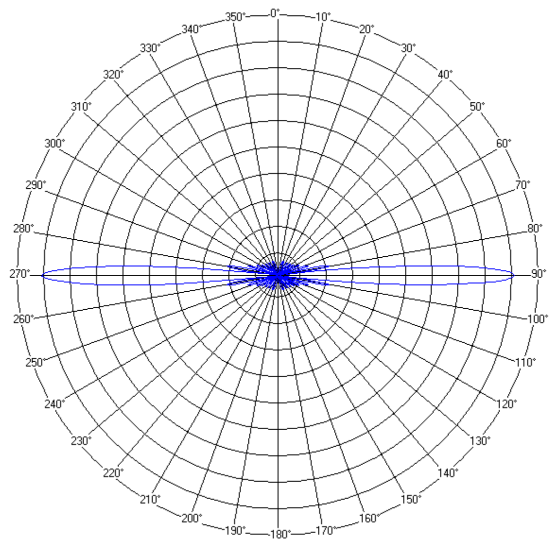
4. LINEAR PHASED ANTENNA ARRAY SIMULATIONS

Phased antenna array simulations are created by the help of program Linear Antenna Arrays Simulator. This program was created in Borland Delphi 7.

The array factor plot in the Figure 3 shows dependency on the element spacing. As we can see from the Figure 3 the antenna pattern is changed by the array element spacing increasing.



d = 1/4 λ

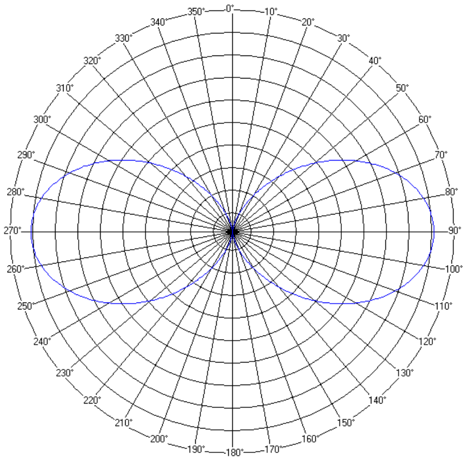


d = 1/2 λ

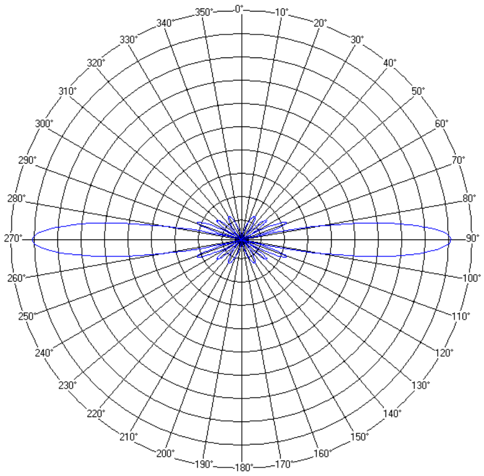
Fig. 3. Set of array factor plots for influence of mutual element's distance simulation

Parameters of simulations were N =16, f = 2 GHz, φ = 0°. Distance of elements d was changed from 1/4 λ to 1/2 λ.

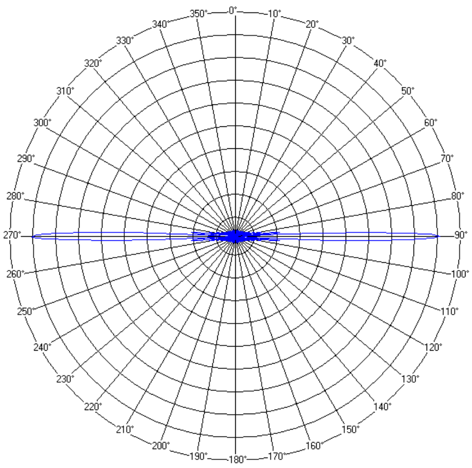
Figure 4 shows that the antenna pattern width is not only dependent on the element spacing but also on the number of elements. It can be seen from Figure 4. the beam width increases as the number of elements in the array increases. Please note that the element spacing is kept constant in both the cases.



$N = 2$



$N = 8$

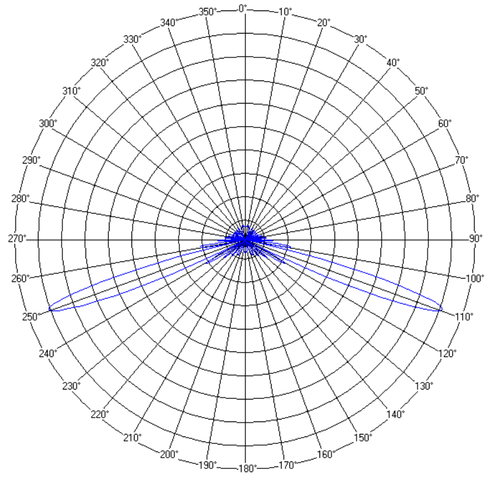


$N = 32$

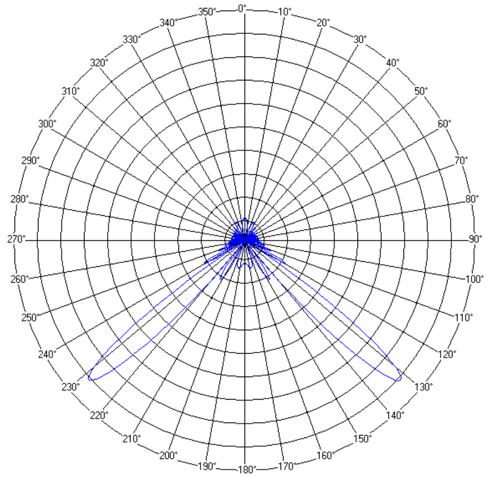
Fig. 4. Set of array factor plots for influence of elements number increase simulation

Parameters of simulations were $d = 1/2\ \lambda$, $f = 2$ GHz, $\varphi = 0°$. Number of elements N was changed ($N = 2, 8, 16$).

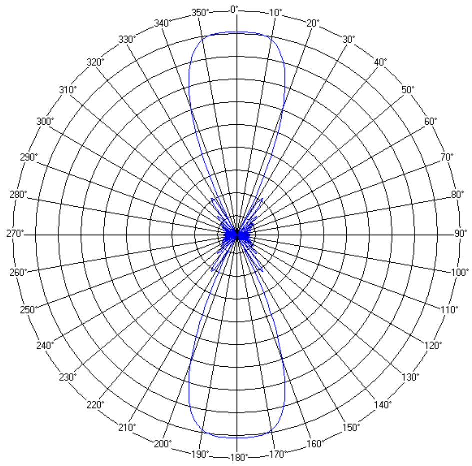
There is shown dependency between antenna pattern orientation and phase shift in Figure 5.



$\varphi = 60°$



$\varphi = 120°$



$\varphi = 180°$

Fig. 5. Set of array factor plots for phase shift change simulation

Parameters of simulations were $d = 1/2\ \lambda$, $f = 2$ GHz, N = 16. Phase shift φ was changed ($\varphi = 60°$, $120°$, $180°$).

As shown in Figures 6 and 7, antenna pattern width is the same if number of elements increases and element spacing is decreases.

At the same time number of elements increases from 10 to 20 elements and element spacing is decreases from $d = 1/2\lambda$ to $d = 1/4\lambda$ and beam width does not change.

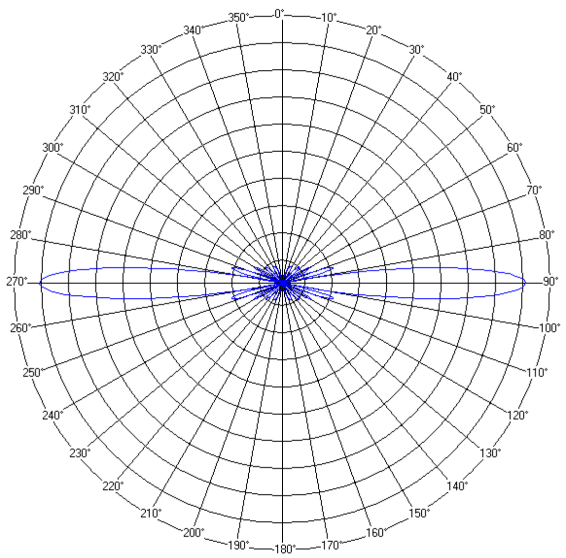


Fig.6 . Relationship between number of elements and the element spacing, d = 1/4λ, N=20

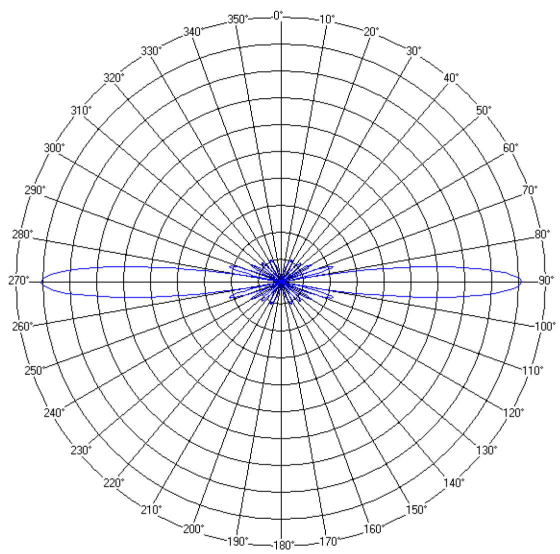


Fig.7. Relationship between number of elements and the element spacing, d=1/2λ, N=10

Parameters of simulations were $f = 2$ GHz, φ=0°.

5. CONCLUSION

In this paper we describe linear phased antenna array theory, simulate this system and describe array factor.

Phased antenna array simulations are created by the help of program Linear Antenna Arrays Simulator. This program was created in Borland Delphi 7.

The final results are described in Figures 3, 4, 5, 6, 7.

As we can see from the Figures 3, 4, 5, 6, 7 the antenna pattern width is not only dependent on the element spacing and on frequency but also on the number of antenna array elements.

We can change antenna pattern orientation by phase shift variation.

Acknowledgement

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